DEVELOPMENT OF A TOOL FOR WHOLE LIFE DESIGN APPRAISAL

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Significant pressures are forcing designers to change the method in which they select components for new facilities. New procurement routes, increased demand for value for money and emerging environmental penalties are examples. There is a lack of understanding of whole life design appraisal techniques in the industry, with issues such as maintenance costs, component durability, sustainability and taxation all presenting complex scenarios. The aim is to demonstrate the development of a web-based tool for whole life design appraisal. A model is proposed that will assist designers in the timely selection of the optimum mix of building components to suit both the immediate and long-term performance requirements of a facility. This is achieved by providing designers with practical guidelines that translate minimal inputs into simple and concise outputs by interpreting data from a range of different sources. Future holistic whole life appraisal models will be able to produce more detailed specifications as designs develop, however, in achieving this vision more collaboration will be required between all parties involved throughout the supply chain of a built facility.

Keywords: cost, design, internet, risk, whole life

INTRODUCTION

Authorities are moving from being owners and operators of assets into becoming intelligent clients purchasing long-term services. For over a decade governments have been putting some major construction facilities out to tender to the private sector. This is demanding a transformation of the roles and responsibilities of all those involved in the procurement and operation of new facilities. The Private Finance Initiative is one such form of Public Private Partnership and involves the public sector purchasing services instead of capital assets. The new facilities are built, financed and run by the private sector, with the government rationale that their involvement will save the public purse and bring private sector efficiency. Private sector contractors can therefore no longer simply build facilities and hand them over, but they need to take an involvement in planning the operation and maintenance of assets that are required to deliver value for money.

Achieving sustainability in construction procurement is becoming a vital issue. Green tax bills are due to come into effect (Pearson, 2001). The government has put together a framework and set of goals to move and to measure progress in a sustainable direction by 2003 (Office of Government Commerce, 2000). Included are commitments that will result in procurement in line with value for money principles on the basis of whole life costs, less waste during construction and operation, targets for energy and water consumption, the protection of habitat and species, targets

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developed in terms of "respect for people" and a contribution to the goals of less pollution, better environmental management and improved health and safety.

RESEARCH INTERVIEW FINDINGS

To achieve satisfactory commercial results in response to these challenges, new private consortiums must design facilities with whole life performance in mind. This change of approach, however, is not without difficulties, particularly on the financial negotiations and associated risk allocation, with whole life cost calculations being at the heart of the problem. Whole life costs include the reconciliation of all expenditure and revenues associated with the acquisition, operation, maintenance, renewal, adaptation and disposal of a facility.

Research interviews with leading design professionals found that the currently available whole life cost data is not ideal, but it is sufficiently adequate to make an informed decision. The main problem is that the required data is not easily accessible and component performance and cost statistics are rarely being fed back from facilities managers to designers. The cause of this is twofold. Firstly, most facility owners are not storing data efficiently – meaning that it is very difficult to retrieve information. Secondly, designers do not have the spare time to take a committed interest in a finished product, and they are even reluctant to do so because it may expose them to liability beyond their present obligations. Therefore, designers often have to rely on intuitive estimates prepared by cost estimators – to whom designers would prefer not to depend upon. In this predicament designers feel that it is too easy for data to be manipulated to suit an individual's attitude or bias. This is resulting in inconsistencies that use so many assumptions that the results are almost futile.

Additional meetings and discussions with other researchers in the whole life design domain, together with contractors, manufacturers and clients, have confirmed the problem that the industry is having with determining reliable whole life cost predictions. Despite a great demand for it to be carried-out, it is rarely being done. Data accessibility and risks analysis are the biggest problems facing design consortiums, and there is an urgent need for an integrated appraisal tool for use during the early appraisal stage of a proposed new facility.

WHOLE LIFE APPRAISAL

Twenty years ago Flanagan and Norman (1983) explained that it is unfortunate that the published sources of whole life appraisal data do not have sufficiently wide coverage to allow their effective use. Today, the most comprehensive occupancy cost information in the UK is published by Building Maintenance Information (BMI). BMI compiles several appropriate documents, including an annual maintenance price book (BMI, 2001a), quarterly cost briefings (e.g. BMI, 2001b) and special reports (e.g. BMI, 2001c). These are all useful sources of cost data for enabling designers to build-up composite component and elemental rates for the purposes of whole life appraisal. The effective use of such information is demonstrated in BMI's occupancy cost plan studies (e.g. BMI, 2000). However, the reality is that designers do not have the time or resources to put the technique into practice when attempting to optimise project solutions during initial design.

In most early stage whole life appraisal situation, BMI data will only allow indicative square metre rates to be applied to total gross floor areas to give strategic budgetary estimates. This rate gives no consideration to the often-unique mix of components for a scheme. Most cost estimators believe that initial capital cost estimates based on the cost per square metre method is insufficient and therefore a risky approach to adopt. They prefer to base forecasts on approximate quantity measurements for individual components. The same rationale applies to whole life cost calculations.

If adequate time is made available to compile an occupancy cost estimate based on approximate quantities, then the results will be most beneficial for aligning maintenance and adaptation requirements with the whole life business plan for a proposed facility. This will be achieved by selecting components that maximise functional continuity and minimise temporary disruptions, downtime and even possible temporary relocations. However, the problem with the BMI approach is that essential information, such as the service life of components, taxation and the cost of cleaning, is still required from other sources. This issue is the restriction of the BMI method for use by designers because they are required to search for information from many additional organisations, including manufacturers, authorities and contractors. This task would be an onerous one for a cost estimator, whose efforts would need to be in addition to the limited time constraints that are normally available to prepare the capital cost estimate.

The Office of Government Commerce (2001a) has stated that historical whole life cost data is not appropriate. Their procurement guidance concludes that where historical data is available, it reflects past mistakes, and that it is always preferable to estimate the costs from first principles. However, this could be construed as contradicting an associated guidance document that promotes project evaluation and feedback (Office of Government Commerce, 2001b). What is therefore required is a system that will use intelligent mechanisms and search engines to quickly bring the different sources and types of whole life data together. Vast “banks” of numbers exist, but they are not being utilised. There is a need to connect these islands of information in an easily accessible way to enable designers to efficiently evaluate the pertinent issues for the purpose of whole life appraisal.

DEVELOPMENT OF A TOOL FOR DESIGNERS

In developing a conceptual model for whole life design appraisal, it is useful to consider the way in which designs develop for new build facilities. Approaches to design can depend on the client, the procurement route and the type of facility. There are many different ways of getting from “A to B”. Generally, approval gateways exist for appraisal, design, tender and site working, however, the key issue is to establish what type of components should be specified before its actual design modelling begins. As nearly all clients are financially driven, this primarily involves calculating how much a facility is going to cost, and thus providing a viable framework for subsequent design development control.

It is believed that approximately eighty per cent of the whole life costs are built into a facility during the first twenty per cent of the design period. The initial design brief of outline objectives should reflect the period from design and construction, to the immediate user requirements and the long-term occupancy plan for the proposed facility. The facility’s design life and frequency of refits must therefore be anticipated, and the results of the appraisal should be used to influence what is to be designed. This can be achieved by making future running costs highly visible, thus convincingly proving that it is beneficial to spend more funds on the initial product to make savings later.

Currently available commercial whole life design appraisal software packages lack the flexibility and information needs required by designers. They are inadequate because they are not link to the best sources of cost and performance data, and do not provide the "rule-of-thumb" guidelines needed by designers when there is pressure to quickly specify components in the critical early appraisal stage of a project. In recognising this shortfall as a research opportunity, the principal aim of this research is to demonstrate the potential of an intelligent whole life design appraisal tool, to be used by designers, for selection of the optimum mix of building components for a proposed new facility.

To provide designers with the relevant decision-making information, accessible timely and concisely, an Internet portal is proposed. This will automate the laborious and time-consuming task of data mining. The World Wide Web is the means of achieving this, and it's unique potential has been proven with similar tools that are available to the general public, for example, to select a rail or airline ticket, and in the construction sector, such as through the Building Cost Information Service (BCIS, 2001), where the service has seen a 70% growth in subscribers since going onto the web (Chartered Surveyor Monthly, 2001). The proposed whole life design appraisal tool will act as a web-based platform that will have several "sockets". Suppliers of the various whole life design data sources will provide the "plugs" for the sockets.

MODEL OUTPUT REQUIREMENTS

So far the emphasis in this paper has been on the cost element of whole life design appraisal. However, when choosing between the various competing options that fulfil the minimum performance requirements, several other important factors enter the equation. A whole life design appraisal summary for a building component should comprise following constituents:

- Installation time – The programme period required to design, manufacture and position the component in situ.
- Capital cost – The price that must be paid for design, purchase and installation of the component.
- Forecast service life – The period of time after installation that the component will meet the minimum performance requirements.
- Operation and maintenance cost – The running cost of the component during its whole life use, including any necessary renewal and adaptation cost.
- Disposal cost-value reconciliation – The balance between the cost of removing the component from the facility and any salvage value.
- Monetary benefits – Income such as an increase rental value for providing a facility with a particular type of component.
- Qualitative benefits – The component's performance value for the "softer" issues that cannot be easily quantified, e.g. safety, aesthetics and user-satisfaction.
- Life cycle assessment – Evaluation of the green / sustainability issues of the component.

This list reflects the key output information for the proposed tool. It must be backed-up with detailed build-ups explaining the occupancy instruction applied, the sources of information used and the assumptions made.

The initial conceptual model focuses on the first five items listed above, i.e. the time and cost features. Monetary benefits, qualitative benefits and life cycle assessment scores are softer issues that are more subjective and thus difficult to quantify. They are, however, still regarded as being important ingredients and they should be incorporated in future models.

MODEL INPUT REQUIREMENTS

Having identified the outputs from the tool, it is possible to determine the required inputs. The inputs from designers for whole life design appraisal of a building component are limited to just eight parameters:

- Facility type / functional location – This determines the typical performance properties of the component and the agents of degradation.
- Site location – The geographical positioning influences the installation time and cost of the component, with the regional weathering agents affecting the forecast service life.
- Base date – The future running costs of the component will be discounted to present day and considered alongside the capital cost.
- Approximate quantity – This will be used for all cost and installation time calculations.
- Design life – The period that the component is required to be an integral part of the proposed facility before being made obsolete.
- Minimum service life – The period that the component must be functional before needing to be replaced.
- Speed of installation – To be viable the component must comply with the programme that is set to deliver the facility on time. This parameter is also applicable to replacement time periods.
- Key component interface – This will allow the adjoining agents of degradation to be identified and is also used to detect any conflicts between the final mix of component specified.

In order to achieve the “rule-of-thumb” guidelines needed by designers, it is necessary to translate the attribute input information into simple and concise output data by interpreting the uncertain figures from the range of different sources.

Prior to appraising a component, the facility type and site location should be known. The first task is then to consider the facility’s whole life and strategic performance requirements (ISO 15686-1, 2000). This study must determine the overall design period and lead-time, tender and site construction periods, facility’s design life, and anticipated intervals for refits, refurbishments and change of use. The plan can then be presented in a simple Gantt chart. This plan may then be used to determine the minimum service lives of individual components across the whole life of the facility. It will help to identify the components that are to be permanent and those that must be replaceable. It is also necessary to prepare a list of component approximate quantities and a functional area schedule, which must be measured from preliminary drawings of plans and elevations. Upon selecting a component to be appraised, the designer will refer to the Gantt chart to determine the specific timing related to the component. This will then be plotted on a more detailed component level programme.

THE CONCEPTUAL MODEL

Figure 1 shows how the tool will work. First the component’s functional performance requirements and agents of degradation will be extracted from the facility’s database. These will be presented to the designer in a simple format for designers to accept or modify. Next, the components that meet the minimum performance criteria will be extracted from the component database. The forecast service lives of the options will be adjusted based on the facility's agents of degradation and site location. Those that have a life less than the required minimum service life will not be considered. For the remaining ones the installation, operation, maintenance and disposal constants will be extracted and the information used to calculate total times and costs by utilising appropriate databases.

The results are presented in a concise format for decision-making and the designer will then send the selected component specification to a whole project facility model. This process will be repeated for each component and, upon completion of every component, a clash-detection system will be run to detect any mismatch between the selected components. Where components are found to be incompatible the system will do further searches and suggest alternatives. It will also detect any knock-on effects, for example, the selection of a particular flooring system may affect the structural height between floor levels, the loading and the foundations design. Results will also include the ancillary cost data required (e.g. skirting, underlay and trims for a floor finish), and it will produce cash-flow graph for the whole life of the facility. Finally, the tool will automate production of the outline design brief.

RISK ANALYSIS

The Davis Belfield & Everest (1977) method of initial capital cost estimating will be adapted for whole life cost estimating, using size and specification to determine budget costs. A predictive model will make explicit the assumptions about risk, and also utilise historical feedback data as a means of validating the allowances for the possibility of repairs and failure. The data that has an effect on the results will automatically be identified, and Flanagan *et al.*'s (1987) method of sensitivity analysis and Monte Carlo simulation is to be adopted and developed.

Behind the simple facade will be dynamic simulations running with optimisation algorithms. The Monte Carlo simulation method of evaluating an influence diagram has become known as "dynamic risk analysis" (Simon *et al.*, 1997). With this approach the influence effects generated at one node are transferred to the next, where they are combined with all other influences before being transferred to the next node, and so on until the final node is reached. Designers will then be able to carry out "what-if" analyses of the different options, using various combination of the variables, with the perceived most likely scenario being compiled in a project risk register. This will aid the correct ownership of risk allocations and help to provide insurability for cost and performance predictions.

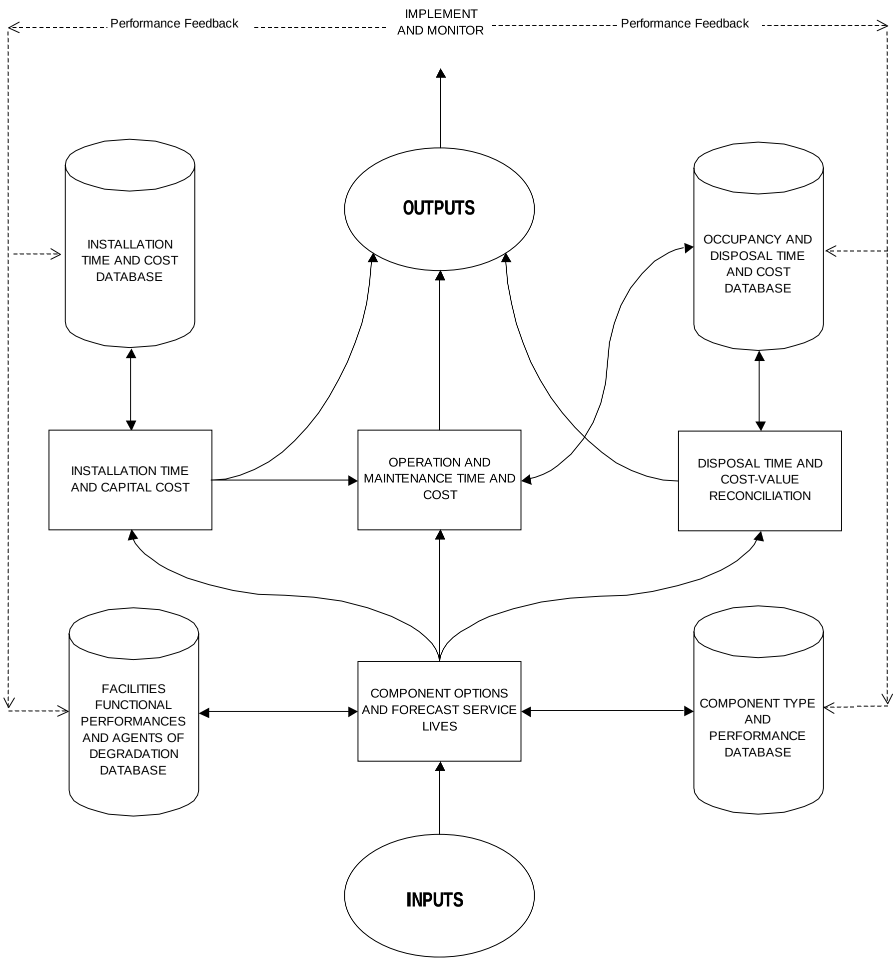

Figure 1: A conceptual model for whole life design appraisal

DATA MANAGEMENT

The four databases shown in Figure 1 will be managed by different specialist organisations. The facilities functional performances and agents of degradation databases may be maintained by client organisations. The component type and performance databases will be maintained by established specialists such as Building Performance Group (BPG, 2001) and Housing Association Property Mutual Limited (HAPM, 2001), being achieved through collaborations with component manufacturers. The installation time and cost databases might be maintained by publishers such as the BCIS and Spon (Davis Langdon and Everest, 2000). Finally the occupancy and disposal time and cost databases may be run by experts such as BMI, who could extend their present service through collaboration with statutory authorities, operation and maintenance contractors and insurance companies. To be effective each database should rely on both original first principle data and performance information fed back from the facilities supply chains. The latter will be achieved through proposed feedback mechanisms that will allow risk profiles to be constructed for the purposes of future simulations. This will reduce the need for designers to take a whole life involvement in facilities, as the tool's feedback system will facilitate the process of learning from past performance.

CONCLUSION

With the recent advances in the power of information technology systems, the whole life design appraisal tool discussed is a viable decision support method of selecting optimum building components at project briefing. Looking further into the future, holistic whole life appraisal models will be able to produce more detailed specifications as designs develop, including complete operation, maintenance and health and safety manuals. When appropriate, the designers will be able to import intelligent objects that are supplied via manufacturers on the web into their CAD packages. These will contain all the whole life data in a dynamic form. The selected virtual objects will live with the actual built facility, linking to sensors and building management systems that are embedded in the structure, fabric and services. These will automatically monitor the costs and performance of components, enabling recorded data to be fed back to designers. In achieving these aims, however, greater collaboration will be required between all parties involved throughout the supply chain of a facility.

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